



GROUNDWATER POLLUTION PREVENTION, MONITORING AND RESPONSE ACTION PLAN

Pinedale Anticline Project Area
Sublette County, Wyoming



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Wyoming State
Engineer's Office

Wyoming Oil and Gas
Conservation Commission

 **NewFields**

SECTION I

Introduction



GROUNDWATER POLLUTION PREVENTION, MONITORING AND RESPONSE ACTION PLAN

Pinedale Anticline Project Area
Sublette County, Wyoming





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GLOSSARY OF ACRONYMS AND SYMBOLS

TERM	DEFINITION
AO	Authorized Officer, Pinedale Field Office, Bureau of Land Management
APD	Application for Permit to Drill
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BLM	US Bureau of Land Management, US Department of Interior
BMP	Best Management Practice
BOPE	Blowout Prevention Equipment
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CAS	Chemical Abstracts Service
CBM	Coal Bed Methane
CFR	Code of Federal Regulations
CGF	Centralized [Liquids] Gathering Facility
COA	Conditions of Approval
COE	Army Corps of Engineers
DA	Natural Gas Development Area
DEQ	Wyoming Department of Environmental Quality
DP	Development Plan
DQO	Data Quality Objective
E&P	Exploration and Production
ECM	Environmental Compliance Manual
EDD	Electronic Data Deliverables
EDMS	Environmental Data Management System
EIS	Environmental Impact Statement
EO	Executive Order
EPA	US Environmental Protection Agency, Region VIII
ERRP	Erosion Control, Re-vegetation, and Restoration Plan
FSEIS	Final Supplemental Environmental Impact Statement
GMP	Groundwater Monitoring Program
GWPC	Groundwater Protection Council
HDPE	High-Density Polyethylene
HSU	Hydrostratigraphic Unit
LGS	Liquids Gathering System
LLPHC	Low-Level Petroleum Hydrocarbon Compounds
mg/L	Milligrams per Liter
MOV	Motor Operated Valve
NPDES	National Pollutant Discharge Elimination System
NLTs	Notice to Lessees
O&G	Oil and Gas
OO	Onshore Oil and Gas Order
OPA	Oil Pollution Act
Operators	Companies involved in natural gas exploration and production in the PAPA



TERM	DEFINITION
P&A	Plugged and Abandoned
PAPA	Pinedale Anticline Project Area
Plan or the Plan	Groundwater Pollution Prevention, Monitoring and Response Action Plan
POT	Project Oversight Team
ppb	Parts per Billion
ppm	Parts per Million
PVT	Pit Volume Totalizer
QAPP	Quality Assurance Project Plan
RAP	Response Action Program
RBDMS	Risk Based Data Management System
RCE	River Corridor Envelope
RCRA	Resource Conservation and Recovery Act
RMP	Resource Management Plan
RMT	Reservoir Management Team, Bureau of Land Management
ROD	Record of Decision
ROW	Rights-of-Way
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Title III Reauthorization Act
SCADA	Supervisory Control and Data Acquisition
SCCD	Sublette County Conservation District
SDS	Safety Data Sheets
SDWA	Safe Drinking Water Act
SEO	Wyoming State Engineer's Office
SPCC	Spill Prevention, Control and Countermeasure Plan
SRP	Spill Response Plan
SUP	Surface Use Plan
SWPPP	Stormwater Pollution Prevention Plan
TDS	Total Dissolved Solids
TEG	Triethylene Glycol
TUP	Temporary Use Permit
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water
USGS	US Geological Survey
VRP	Voluntary Remediation Program
VSP	Visual Sample Plan
WDEQ	Wyoming Department of Environmental Quality
WEQA	Wyoming Environmental Quality Act
WOGCC	Wyoming Oil and Gas Conservation Commission
WSEO	Wyoming State Engineer's Office
Wyo. Const.	Wyoming Constitution
Wyo. Stat.	Wyoming Statutes Annotated

APPROVAL

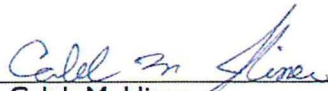
**GROUNDWATER POLLUTION PREVENTION, MONITORING AND RESPONSE ACTION PLAN
PINEDALE ANTICLINE PROJECT AREA, SUBLETTE COUNTY, WYOMING**

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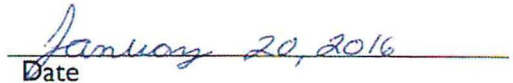
Bureau of Land Management Record of Decision: Groundwater Resources, Step 3
Pinedale Anticline Supplemental Environmental Impact Statement, Sublette County, Wyoming

And

Wyoming Oil and Gas Conservation Commission Rules and Regulations: Chapter 3, Section 46
Master Groundwater Baseline Sampling, Analysis and Monitoring Plan
for the Pinedale Anticline, Sublette County, Wyoming



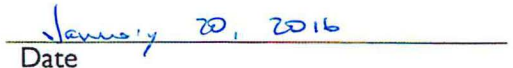
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1.0 INTRODUCTION

This Groundwater Pollution Prevention, Monitoring and Response Action Plan (Plan) was prepared for the Pinedale Anticline Project Area (PAPA), a natural gas development in Sublette County, Wyoming. The Plan complies with a September 2008 Record of Decision (ROD) by the U.S. Department of Interior (DOI) Bureau of Land Management (BLM) regarding the Supplemental Environmental Impact Statement (SEIS) for the Pinedale Anticline Oil and Gas Exploration and Development Project Area. As part of this ROD, BLM approved development of the oil and gas resources within the PAPA as outlined in Alternative D of the Final SEIS (BLM 2008a), as modified in the ROD (BLM 2008b). The ROD emphasizes concentrating development, allowing for systematic development, reducing impacts using performance based outcomes and adaptive management, and cooperative monitoring with the State of Wyoming (BLM 2008b).

In addition to complying with requirements of BLM's ROD, this Plan also satisfies regulations promulgated by the Wyoming Oil and Gas Conservation Commission (WOGCC). Beginning in March 2014, the WOGCC required a groundwater baseline sampling, analysis and monitoring plan as part of the Application for Permit to Drill or Deepen a Well (WOGCC 2014a; Operational Rules, Drilling Rules; Chapter 3, Section 46). WOGCC rules allow for a "master plan" to address a particular geographic area of development; this Plan is intended to serve as the master groundwater baseline sampling, analysis and monitoring plan for the PAPA.

This Plan was developed through a deliberate, collaborative process involving BLM and WOGCC, three other agencies (Wyoming Department of Environmental Quality [DEQ], Wyoming State Engineer's Office [SEO], and the U.S. Environmental Protection Agency [EPA]), two oil and gas operators (Ultra Resources, Inc. [Ultra] and QEP Energy Company [QEP], collectively referred to as "UQ" or the Operators), and an environmental consultant (NewFields Mining and Energy Services LLC [NewFields]).

1.1 PURPOSE OF THIS PLAN

This Plan is dedicated to describing the means to be used to protect groundwater resources from potential impacts that could result from natural gas exploration and production (E&P) activities. Comprehensive groundwater studies in the PAPA spanning 2007-2013 found that there is no evidence of widespread impact to groundwater in the PAPA caused by sources associated with natural gas E&P, including those activities that created spills or leaks of materials used in, or by-products of, natural gas development. These studies are summarized in **Section 1.6**. Nevertheless, BLM's 2008 ROD requires a multi-faceted plan be developed to formalize groundwater pollution prevention practices, describe future groundwater monitoring in the PAPA, and respond to potential future circumstances related to pollution prevention or groundwater monitoring.

This Plan was developed to meet two specific regulatory requirements. Operators in the Pinedale Anticline will use the Plan to comply with Step 3 of BLM's 2008 ROD (Section 4.2 of BLM 2008b). The Plan will also serve as the Operator's master groundwater baseline sampling, analysis and monitoring plan for the PAPA, in general conformance with WOGCC's regulations as recorded in Section 46, Chapter 3 of the "Operational Rules, Drilling Rules" (WOGCC 2014a).



1.2 UNDERSTANDING THIS PLAN

Fundamentally, this Plan was developed to protect groundwater resources from potential impacts associated with E&P activities in the PAPA. The primary means of gaining protection is through employment of an array of best management practices (BMPs) designed to prevent groundwater pollution. To evaluate the adequacy and effectiveness of the suite of BMPs, the Plan will rely on results from routine, comprehensive groundwater monitoring at locations throughout the PAPA development area. Confirming both the adequacy of the BMPs and evaluating monitoring results for evidence of potential groundwater degradation will occur on an on-going basis. Should monitoring indicate that a BMP has failed or a new BMP is needed, and/or that a groundwater quality threshold has been exceeded, specific actions for response are set forth in this Plan. Based on the foregoing and as depicted on **Figure 1-1**, three interrelated programs form this Plan:

- Groundwater Pollution Prevention Program;
- Groundwater Monitoring Program; and
- Response Action Program.

This Plan is organized around these three programs and details are provided in subsequent sections. Background information for the Plan is presented in this introductory section, including: a description of the PAPA; explanation of the agencies involved in the Plan and their jurisdictions; presentation of project administration; summaries of previous groundwater studies in the PAPA; and descriptions of the groundwater data sources and data management system for the Plan. Beyond this introductory section, goals and detailed objectives that were established for the Plan are presented in **Section 2.0**. The last three sections of this Plan describe each of the three programs (**Section 3.0** - Pollution Prevention; **Section 4.0** - Groundwater Monitoring; and **Section 5.0** - Response Action).

Although the three programs are interrelated as shown on **Figure 1-1**, each of the five sections of this Plan is organized separately. All references cited in each section are presented at the end of the section text. Specific figures, tables and appendices germane to a particular section are contained at the end of the section.

1.3 PROJECT AREA DESCRIPTION

The PAPA covers approximately 309 square miles of federal, state, and private land, with an approximate maximum width of 14 miles and length of 30 miles (**Figure 1-2**). The BLM manages 80 percent of the land within the PAPA. Natural gas E&P activities within the PAPA target natural gas accumulations within a subsurface structural trap called the Pinedale Anticline. The Pinedale Anticline crest is approximately 2 to 3 miles wide, and is oriented northwest to southeast, parallel to the Wind River Range located to the east, and is generally delineated by the North Anticline, Middle Crest and Jonah North roads shown on **Figure 1-3**. The following sections summarize the physical, geologic and hydrogeologic setting of the PAPA, largely adapted from AMEC (2013a, 2013b).



1.3.1 Physical Setting

The PAPA is located in a broad valley oriented northwest to southeast between the Wind River and Wyoming Mountain ranges (**Figure 1-2**). The area is characterized by a semiarid climate with rocky soil, sparse vegetation, and numerous ephemeral drainages dissecting ridges and buttes. Major drainages include the New Fork River, East Fork River, and Green River (**Figure 1-3**). Topographic elevations range from approximately 6,850 feet above mean sea level (amsl) where the New Fork River exits the PAPA to over 7,700 feet on top of the “Mesa” in the north-central portion of the PAPA. Sagebrush communities characterized by shrub-steppe vegetation dominate the PAPA (BLM 2008b); riparian vegetation and wetlands occupy floodplains of the New Fork and Green rivers.

1.3.2 Geologic and Hydrogeologic Setting

The petroleum system currently exploited in the PAPA consists of a thick interval of low-porosity and low-permeability Cretaceous-age rock within the Pinedale Anticline (refer to Figure 2-4 in AMEC 2013b). Cretaceous-age sediments in the PAPA were deposited in a marine environment, which eventually transitioned into an alluvial plain depositional environment. The sediments that host the gas reservoir include sandstones, siltstone, mudstones, and carbonaceous shale units of the Cretaceous-age upper Mesaverde and Lance Formation, as well as the Tertiary-age Unnamed Unit. These gas-bearing sediments are collectively referred to as the Lance Pool, which is an over-pressurized, tight gas reservoir located 8,000 to 14,000 feet below the ground surface (ft bgs). Twenty natural gas wells were drilled in the PAPA between 1939 and 1982 to tap the Lance Pool (i.e., pre-1984 wells). Since 1994, the drilling of natural gas production wells rapidly increased due in part to improvements in drilling and hydraulic fracturing technology. Most of the natural gas E&P activities are concentrated along the entire length of the crest of the anticline (refer to Figure 2-8 in AMEC 2013b).

The collective sediments of the Lance Pool are overlain by approximately 8,000 feet of Tertiary-age sedimentary rocks of the Fort Union and Wasatch formations. These sediments consist of interbedded shale, siltstone, and sandstone that were deposited in fluvial deltaic and alluvial plain environments. Groundwater in the Wasatch Formation, the uppermost water-bearing zone along the axis of the Pinedale Anticline, is tapped to support natural gas E&P activities, as well as domestic and stock uses. The deepest industrial water supply wells are approximately 1,000 to 1,200 ft bgs, which is approximately 7,000 feet above the top of the Lance Pool. In some discrete areas of the PAPA, Tertiary-age formations are overlain by unconsolidated Quaternary- and Holocene-age sediments.

Regionally, groundwater generally flows westward and southward from the mountains and foothills of the Wind River Range, where it is recharged, toward the Green River below the mouth of the New Fork River and into the center of the Green River Basin (AMEC 2012). Groundwater flow is toward the south in the PAPA north of the New Fork River; groundwater flow is toward the west in the PAPA south of the New Fork River (see **Figure 4-4** in **Section 4.0**). Some recharge to the Wasatch Formation may occur within the PAPA (see Section 7.8.2.1 in AMEC 2012). Groundwater in the Wasatch Formation hydrostratigraphic unit (HSU) (AMEC 2012, 2013a) is typically present under semi-confined conditions due to the heterogeneous nature of the formation. Estimated average groundwater velocity in Wasatch Formation sandstone units ranges from 0.011 to 40 ft/year (AMEC 2012). The towns of Pinedale and



Boulder are located upgradient of natural gas E&P activities in the PAPA with respect to groundwater flow direction.

Alluvial sediment in the river corridors is in hydraulic communication with groundwater in the Wasatch Formation, and receives and transmits groundwater down-valley and into the New Fork River in the central PAPA. Vertical hydraulic gradients in alluvium in the upper New Fork River valley vary seasonally, but are upward most of the year (AMEC 2012). Numerical modeling results indicate that groundwater transport velocities in alluvial material along the New Fork and Green rivers are 100 to 700 times greater than those in the Wasatch Formation (AMEC 2013a).

1.4 AGENCIES INVOLVED AND JURISDICTIONS

One of the major topics addressed in the 2008 ROD focused on protection of groundwater resources (e.g., current and future drinking water sources), particularly as it relates to detection of hydrocarbons in industrial water supply wells. The ROD for groundwater resources (Section 4.2 in BLM 2008b) describes a cooperative effort between technical specialists from BLM, regulatory agencies, and the Operators in fulfilling requirements specified in the ROD.

The ROD instructs the BLM, Operators, Wyoming DEQ - Water Quality Division, and EPA to develop an Interim Groundwater/Aquifer Pollution Prevention, Mitigation and Monitoring Plan (Interim Plan) and funding strategy to initiate groundwater characterization efforts and augment existing monitoring programs, as necessary (BLM 2008b). A key purpose of the Interim Plan was to identify mitigation for all potential sources of contamination until a potential source is determined not to be contributing to contamination (BLM 2008b). The Interim Plan was published in December 2008 (AMEC Geomatrix 2008).

Work has been underway since 2009 to address this requirement, the latest of which has culminated in production of this interagency Plan. Given the diverse involvement of various state and federal agencies in addressing groundwater issues on lands associated with the PAPA, and in both developing and implementing this Plan, the following sections provide a synopsis of relevant roles and responsibilities of these agencies, including a brief discussion of the enabling legislation and rules which govern the responsibilities.

1.4.1 Bureau of Land Management

The BLM has broad authority to regulate onshore oil and gas operations under 43 Code of Federal Regulations (CFR) Part 3160, associated with the exploration, development and production of oil and gas deposits from leases issued or approved by the United States. This includes a provision under 43 CFR 3162.1(a) requiring that “the operating rights owner or operator, as appropriate, shall comply with applicable laws and regulations; with the lease terms, Onshore Oil and Gas Orders, Notice to Lessees (NTLs); and with other orders and instructions of the authorized officer. These include, but are not limited to, conducting all operations in a manner which ensures the proper handling, measurement, disposition, and site security of leasehold production; which protects other natural resources and environmental quality; which protects life and property; and which results in maximum ultimate



economic recovery of oil and gas with minimum waste and with minimum adverse effect on ultimate recovery of other mineral resources”.

Specific to control of wells and protection of water resources, 43 CFR 3162.5-2(d) states that the “The operator shall isolate freshwater-bearing and other usable water containing 5,000 parts per million (ppm) or less of dissolved solids and other mineral bearing formations and protect them from contamination.” This section also states that tests and surveys of the effectiveness of such measures shall be conducted by the operator using procedures and practices approved or prescribed by the BLM’s Authorized Officer (AO). In 43 CFR 3160.0-5, fresh water is defined as “water containing not more than 1,000 ppm of total dissolved solids, provided that such water does not contain objectionable levels of any constituent that is toxic to animal, plant or aquatic life, unless otherwise specified in applicable notices or orders.”

Further clarification related to “usable” water is provided via Onshore Oil and Gas Order No. 2 (effective December 19, 1988) detailing BLM’s uniform national standards for the minimum levels of performance expected from lessees and operators when conducting drilling operations on Federal and Indian lands, and for abandonment immediately following drilling. Order No. 2 defines usable water as generally those waters containing up to 10,000 ppm of total dissolved solids. Order No. 2 also states under a “requirements” section that the proposed casing and cementing programs shall be conducted as approved to protect and/or isolate all usable water zones and that all indications of usable water shall be reported to the authorized officer prior to running the next string of casing or before plugging orders are requested. Isolating means using cement to protect, separate, or segregate usable water and mineral resources (BLM 1988).

Specific to authorities within the PAPA, BLM is tasked with managing the federal surface and mineral estate as directed in the 2008 ROD and authorizes BLM’s AO to process Applications for Permits to Drill (APD), Sundry Notices, Rights-of-Way (ROW), and Temporary Use Permits (TUP) on public lands administered by the BLM, and establishes conditions by which such authorizations and exceptions to seasonal restrictions will be granted with Conditions of Approval (COA) or stipulations. The current 2008 ROD supersedes the PAPA ROD of July 27, 2000 and subsequent decisions (BLM 2008b).

Related to groundwater resources and in accordance with the 2008 ROD (BLM 2008), BLM is tasked with continuing to work with various regulatory agencies and the Operators to identify and mitigate causes of contamination associated with detection of hydrocarbons in industrial water wells. The BLM’s Regional Framework for Water Resources Monitoring Related to Energy Exploration and Development (U.S. Geological Survey [USGS] 2007) sets forth guidance for groundwater monitoring and subsequent identification and implementation of mitigations, including compilation of existing information, characterization of the groundwater system, and modification of the monitoring plan. Both the Interim Plan (Amex Geomatrix 2008) and this Plan were developed in consideration of this regional framework as required by the 2008 ROD (BLM 2008).

1.4.2 Wyoming Department of Environmental Quality

While BLM has overarching authorities with regards to managing the federal surface and mineral estate, including regulating oil and gas operations associated with the exploration, development and production



of oil and gas deposits from BLM leases in the PAPA, the State of Wyoming has authority to protect the environment throughout the state via Wyoming Statutes Annotated [Wyo. Stat.] §35-11-100 et. seq., or the Wyoming Environmental Quality Act (WEQA). WEQA was established to enable the state to “retain for the state the control over its air, land and water and to secure cooperation between agencies of the state, agencies of other states, interstate agencies, and the federal government in carrying out these objectives.” The Wyoming DEQ was established in 1973 under WEQA to enforce this statute. In addition to WEQA, DEQ is also responsible for enforcing federal environmental laws, including the Clean Air Act and Clean Water Act, National Pollutant Discharge Elimination System (NPDES), Resource Conservation and Recovery Act (RCRA), Superfund Amendments and Title III Reauthorization Act (SARA), and Federal Surface Mining Reclamation and Control Act.

Specific to surface water and groundwater protection provisions under WEQA (Wyo. Stat. §35-11-302), the newly created DEQ was required to establish rules, regulations, standards, and permit systems to promote the purposes of this act. A summary of those pertaining to groundwater is included below:

- Wyoming DEQ’s Water Quality Rules and Regulations, Chapter 3, establishes Regulations for Permit to Construct, Install or Modify Public Water Supplies, Wastewater Facilities and Other Facilities Capable of Causing or Contributing to Pollution. Section 8 of Chapter 3 clarifies that monitoring wells fall under this rule and states that when pollution is found from these facilities that has entered or threatens to enter waters of the state, including groundwater, the property owner or owner of the facility shall immediately notify the DEQ Water Quality Division (WQD) (DEQ 2012). Section 17 of this chapter requires documentation that the facility poses no threat of discharge to groundwater, or if that cannot be provided, a subsurface study shall be provided as part of the application to demonstrate the groundwater standards are adhered to.
- Chapter 8 specifies quality standards for Wyoming groundwater, including the authority, definitions, standards, and classifications for groundwater protection in the state (DEQ 2005). Under Section 2(f) of this chapter "Groundwater" means subsurface water that fills available openings in rock or soil materials such that they may be considered water saturated under hydrostatic pressure". Section 2(g) of this chapter defines "Groundwaters of the State" as all bodies of underground water which are wholly or partially within the boundaries of the State; Groundwaters of the State is synonymous with Groundwaters of Wyoming.
- Chapter 9 outlines the Wyoming Groundwater Pollution Control Permit process which requires permitting when discharging to the subsurface, including the vadose zone, which could render any groundwater of the State unsuitable or degrade it for all uses for which it was suitable prior to discharge (DEQ 1998). Discharges, for the purpose of these regulations, are described and identified in this chapter as: discharges of commercial, municipal and industrial wastes, which include oil field wastes including water produced with oil and gas. Moreover, a monitoring program is required that is “adequate to ensure knowledge of migration and behavior of the pollution or waste whenever the discharge of any pollution or wastes into groundwaters of the State is caused, threatened or allowed; or the physical, chemical, radiological, biological or bacteriological properties of any groundwaters of the State may be altered by man’s actions”.



Various programs exist under DEQ's WQD to implement these rules and requirements relative to groundwater resources. The WQD's Underground Injection Control (UIC) Program protects current and future uses of Underground Sources of Drinking Water (USDW) by regulating the subsurface injection of: waste fluids; subsurface storage of liquid and gaseous fluids; and mineral solution mining. EPA has delegated primary regulatory and enforcement authority to DEQ for Class I, III, IV and V UIC facilities. The WOGCC has primacy for Class II wells (see below) (DEQ 2014a).

The Wyoming DEQ also has responsibility for statewide groundwater monitoring, including establishment of an ambient groundwater monitoring strategy. Results of implementing the monitoring program from November 2009 through September 2012 are found in Boughton (2014). DEQ has conducted a GIS-based groundwater vulnerability mapping project on a county-by-county basis in the state, which is further described in **Section 4.2.2**.

DEQ's Groundwater Pollution Control (GPC) Program evaluates potential impacts to the groundwater of the State by activities permitted at the local, state, or federal level. Among other tasks, the GPC Program oversees sites where groundwater contamination already exists and cleanup is on-going, as well as sites where impacts may occur in the future. Groundwater monitoring tracks the extent and levels of existing contamination, while remediation treats the groundwater to remove contaminants. The GPC Program also issues permits for monitoring wells designed to detect potential contamination originating from coal bed methane (CBM) produced water impoundments that may reach shallow aquifers (DEQ 2014a).

In 2000, the Wyoming legislature created new opportunities, procedures, and standards for voluntary remediation of contaminated sites in Articles 16, 17, and 18 of WEQA (Wyo. Stat. §35-11-1601 through 1803). These are implemented by the DEQ (2014b) through its Voluntary Remediation Program (VRP). According to DEQ, the VRP is a set of comprehensive standards and procedures for voluntary remediation (cleanup) of contaminated sites in Wyoming and replaces other DEQ cleanup programs. Cleanup standards established by the VRP (soil and groundwater) apply to all DEQ-oversight cleanups in Wyoming in an effort to ensure consistency among cleanups and equal protection of human health and the environment throughout the State. The VRP cleanup standards are established in Wyo. Stat. §35-11-1605(a) and by DEQ (2014b). The cleanup standards are consistent with those generally used under federal cleanup programs and with standards that have been used under DEQ cleanup programs that pre-date the VRP. AMEC (2013b) identifies several sites in the PAPA that are or have been enrolled in the VRP.

1.4.3 Environmental Protection Agency

The mission of the EPA is to protect human health and the environment. Relative to groundwater protection, promulgated under the Safe Drinking Water Act (SDWA) (42 United States Code [U.S.C.] §300f et seq.), the EPA, via 40 CFR 141-149, sets standards for drinking water quality and oversees the states, localities, and water suppliers who implement those standards. In Wyoming, EPA and Wyoming state agencies coordinate activities to ensure that consumers are served safe drinking water. As discussed above, EPA delegated authority to the state of Wyoming to regulate UIC facilities. In addition, the Oil Pollution Act (OPA) of 1990 (33 U.S.C. §2701 et seq.) strengthened and streamlined EPA's ability to respond to oil spills via a trust fund financed by a tax on oil in cases when the responsible party is unable to do so (EPA 2012).



The EPA, and its Office of Federal Activities coordinates, via 40 CFR 1500 through 1508, the agency's review of all federal documents prepared by other agencies under the National Environmental Policy Act (NEPA) (42 U.S.C. §4321 et seq.) and also ensures compliance with federal environmental laws. Specific to NEPA activities associated with the PAPA, EPA Region 8 has provided technical assistance and review of draft NEPA documents, including specific comments on the Preliminary Draft SEIS where EPA requested additional information and analysis related to potential existing and potential future impacts on groundwater associated with activities in the PAPA. EPA has subsequently participated in the review of technical groundwater reports, aimed at addressing such questions per the requirements of the ROD (BLM 2008b) and completed subsequent to the Interim Plan (AMEC Geomatrix 2008). Under this Plan, EPA continues to support BLM in a technical advisory role.

1.4.4 Wyoming State Engineers' Office

The Wyoming State Engineer is granted the authority to have general supervision of the waters of the state by Article 8 of the Wyoming Constitution (Wyo. Const.). The State Engineer's Office (SEO) must approve permits for the use of water. The Wyoming State Board of Control is charged with the task of division and distribution of the water resources, by priority, in times of water shortage. Wyoming water law operates under the prior appropriation doctrine, or "first in time - first in right." Those holding an earlier priority water right are allowed to receive their full portion of water before those with junior rights may receive water under their right. Water rights are generally issued for any beneficial use of the water. Recognized beneficial uses include: irrigation, municipal, industrial, power generation, recreational, stock, domestic, pollution control, in-stream flows, and miscellaneous. Water rights holders are limited to withdrawals necessary for the purpose (SEO 2014).

Applicants seeking water for some beneficial purpose must make application to, and secure an approved permit from the SEO authorizing the activity prior to using the water for the desired purpose. The SEO issues permits for all new wells and monitors status of plugged and abandoned wells. In addition, permission of the SEO or Board of Control is required before a permitted water well or spring can be relocated, deepened, or the point(s) and areas(s) where the water is beneficially used can be changed (SEO 2014).

The SEO has general supervision of the waters of the state and is authorized under Wyo. Stat. §41-3-909 to establish standards for the minimum construction of water wells to protect the use of the state's groundwater resources. Water Well Minimum Construction Standards (originally produced in 1974) were updated in 2010. Important changes included that all water well drilling and pump installation contractors must be licensed and all water wells must be drilled by a licensed contractor, with the exception of wells drilled by a landowner on their land (SEO 2014). All water wells constructed from 2010 onward must adhere to these standards.

Regarding PAPA activities specifically, the SEO has stated that many existing permits have attached conditions of use to which the user must adhere to continue the exercise of the use of the water that has been secured through the approved permit. In addition, Industrial Permits associated with the PAPA have conditions of approval related to the manner in which the well must be constructed that mimic those required in the ROD. Moreover, the SEO has also attached a condition of approval that requires these wells be equipped with backflow prevention devices to prevent introduction of contaminants into



the well. There are over 120 Industrial Permits for industrial water supply wells in the PAPA. Wells in the PAPA have a 5-year term for water well permitting consistent with water wells in established oil and gas fields. No recent water wells have been permitted, but SEO has reissued a number of permits.

1.4.5 Wyoming Oil and Gas Conservation Commission

Oil and gas development in Wyoming is governed primarily by statutory provisions in Wyo. Stat. §30-5-100, et seq. and subsequent rules and regulations promulgated by the WOGCC. The WOGCC also handles the drilling permit process and ensures industry compliance with these statewide oil and gas laws and regulations.

Under WOGCC Rules and Regulations, Chapter 4 - Environmental Rules, Section 1 (including Underground Injection Control Program Rules for Enhanced Recovery and Disposal Projects), applications to construct pits will be approved if the pit will not cause the contamination of surface or underground water, and endanger human health or wildlife. Approval by the WOGCC of applications for permits for reserve or produced water pits does not relieve the owner or operator of the obligation to comply with applicable federal, local, or other state permits or regulatory requirements. Under Section 5 of Chapter 4 (Underground Disposal of Water), the underground disposal of fresh water or of salt water, brackish water, or other water unfit for domestic, livestock, irrigation, or other general uses, is permitted only upon order of the Commission or approval of the Supervisor, obtained pursuant to an application filed in accordance with WOGCC rules (WOGCC 2014).

As mentioned in **Section 1.0**, a recent WOGCC rule update (effective March 1, 2014) under Chapter 3, Section 46 (Operational Rules, Drilling Rules) establishes a baseline groundwater testing and monitoring program for oil and natural gas development before and after drilling. This rule does not apply to an existing oil or gas well that is converted to an injection well for enhanced recovery or disposal purposes (WOGCC 2014). Under this update, operators are required to submit a groundwater baseline sampling, analysis and monitoring plan with an Application for Permit to Drill (APD) or Deepen a Well (Form 1). The groundwater monitoring program consists of initial baseline water sampling and testing, followed by a series of subsequent sampling and testing after setting the production casing or liner. Specifically, the rule stipulates that operators perform initial baseline water testing on water sources within a half-mile radius of a planned drill site no more than 12 months before drilling begins. Follow-up water quality testing is then required 12-18 months after production casing or liner has been set, and again 36-48 months later. The rule contains sampling and analysis procedures which set minimum requirements and protocols that must be followed by operators or their contractors (Appendix K; WOGCC 2014). Under Section 46 (I), operators are provided the opportunity to submit a master groundwater baseline sampling, analysis and monitoring plan for a geographic area of development such as the PAPA (WOGCC 2014).

1.4.6 Memorandums

In addition to agency responsibilities outlined individually above, two inter-agency memorandums were established to clarify roles and responsibilities relative to oil and gas operations and use of public and privately owned lands for production and drilling. These memorandums are described below for clarification purposes.



1.4.6.1 State of Wyoming Memorandum of Agreement

A long-standing State of Wyoming Memorandum of Agreement (MOA), signed August 5, 1994, defines the permitting and administrative responsibilities of the WOGCC, DEQ, and SEO regarding water resources related to oil and gas development throughout the state. The purpose of this agreement is to provide an efficient administrative mechanism for permitting of those activities within the overlapping jurisdiction of the parties (DEQ 1994).

The MOA acknowledges that all waters, including groundwater, within the boundaries of the State of Wyoming are the property of the state and control of the beneficial use of water of the state resides with the Wyoming State Board of Control and the SEO. The MOA also states that the SEO is authorized and empowered on advice and consent of the Board of Control to require the abatement of any condition responsible for the admission of polluting materials into any underground water supply. The MOA also states that because protection of the waters of the state is a priority, no construction or action which is not protective of surface water and groundwater of the state shall be authorized by the DEQ, WOGCC, or SEO.

Consistent with what is discussed above, the MOA states that DEQ is responsible for permitting commercial underground disposal into Class I injection wells, and shall be responsible for permitting the disposal of wastes which are not an integral part of primary oil and gas production operations pursuant to the authority granted in the WEQA. DEQ must also permit all other activities relating to the regulation, location, operation, and reclamation of oil field waste disposal facilities and the disposal of oil field wastes, not specifically falling within the jurisdiction of WOGCC.

Similarly, the MOA states that WOGCC is responsible for permitting Class II injection wells used to inject gas and fluids for enhanced recovery and for noncommercial disposal of salt water, nonpotable water, and oil field wastes related to primary oil and gas production. WOGCC is also responsible for permitting the location, construction, operation and reclamation of noncommercial reserve pits, and produced water retention and emergency pits used solely for the storage, treatment and disposal of drilling fluids, produced waters, emergency overflow wastes or other oil field wastes associated with the maintenance and operation of oil and gas exploration and production wells on a lease, unit, or communitized area.

1.4.6.2 Memorandum of Understanding (BLM and WOGCC)

Another long-standing Memorandum of Understanding (MOU) (signed September 21, 1994) is in place between the BLM and WOGCC and reiterates many of the roles and responsibilities discussed above relative to regulation of Class II underground injection wells (BLM 1994; see Appendix 1 of the MOU, Underground Injection Control). Consistent with the MOA discussed above, the MOU notes that the EPA, under provisions of Section 1425 of the SWDA (40 CFR 1425), has delegated authority to WOGCC to administer the UIC program for Class II injection wells on all federal, state, and private lands in Wyoming (excluding Tribal lands). The MOU also recognizes that BLM has authority over development of mineral estate and surface management authority on public lands and has a mandated administrative and technical interest in all injection projects and wells on federal minerals and has a responsibility to participate in the authorizations of these projects and wells (BLM 1994).



For project approvals, notices of applications to WOGCC for Class II projects and aquifer exemptions of federal lands will be provided to the Reservoir Management Team (RMT) of the BLM. If the RMT wishes to comment to WOGCC, it must do so within 15 days of receipt.

For subsequent well operations, the BLM shall accept the UIC program orders issued by WOGCC as approval of an aquifer exemption. However, the BLM shall authorize injection well workovers or plugging or conversion of wells on federal leases. For existing federal wells located in a previously approved project area that are proposed for conversion to an injection well, the applicant must provide a copy of the proposal for BLM review (BLM must comment within 15 days to WOGCC as discussed above).

BLM and WOGCC share responsibility to witness plugging and abandonment operations on federal injection wells and to perform routine inspections on these federal leases with UIC operations. The WOGCC is required to notify BLM of any pollution problems noticed during well inspections on federally administered lands and minerals and the BLM is required to notify the WOGCC of any suspected violations of WOGCC requirements noted during their inspections.

1.5 PROJECT ADMINISTRATION

A project administration plan was developed to address technical studies (see **Section 1.6**) required to complete Step 2 of the 2008 ROD (AMEC Geomatrix 2009). With issuance and acceptance of the final technical report associated with the Interim Plan in November 2013, the BLM determined that Step 2 of the ROD for groundwater resources was completed. In April 2014, a project Administration Plan (NewFields 2014) was developed to address the administrative aspects for completing Step 3 of the ROD for groundwater resources (see Section 4.2 in BLM 2008b).

The project Administration Plan (NewFields 2014) for Step 3 of the ROD identifies project participants and their roles, and describes a Project Oversight Team (POT) and a Review Team (see **Figure 1-4**). Specific process tasks associated with Step 3 are outlined along with a generalized schedule. Finally, methods for conflict resolution are explained along with terms for the Administration Plan agreement between BLM, Operators and the contractor.

A unique aspect of this Groundwater Pollution Prevention, Monitoring and Response Action Plan is the collaboration that occurred between five different agencies (see **Section 1.4**), two distinct Operators and a consultant. Representatives of each entity signed the Administration Plan which was approved by the AO. Each entity had one or more roles in developing this Plan as explained in the following sections.

1.5.1 Project Oversight Team

A Project Oversight Team (POT) was established to guide this Plan from inception to completion. The four-person team includes:

- BLM's AO,
- BLM's Project Lead,



- UQ's contract manager, and
- Project Manager (Primary Consultant or Contractor, currently NewFields).

On a weekly basis the POT met to discuss the project status and to ensure the project was on-track and within the approved process tasks/steps. Any issues identified by the project manager or other POT members were discussed, investigated as necessary, and resolved within the approved process tasks.

The project manager (NewFields) is assigned to work as a quasi, third-party contractor and developed most components of this Plan. In order to maintain authorship of work products and documents, and in keeping with agreed-upon process tasks recorded in the Administration Plan, the project manager made final recommendations to the AO for issue resolution in consideration of input received from the Review Team (see below). The Operators assumed a key role in developing the Groundwater Pollution Prevention Program (**Section 3.0** of this Plan) as they were most knowledgeable regarding the E&P practices being employed in the PAPA.

1.5.2 Review Team

The Review Team for this Plan consists of a Regulatory Team and an Operator Team. Members of the POT also serve on the Review Team. The Regulatory Team is comprised of representatives from BLM, DEQ, WOGCC, SEO and EPA. The BLM, DEQ and EPA were intimately involved with execution of Step 2 of the ROD since 2008; the BLM invited the WOGCC and SEO to participate with Step 3 of the ROD and into the future. Representatives of Ultra and QEP form the Operator Team. Combined, this Review Team provided valuable input to the process of developing goals and objectives for this Plan (**Section 2.0**). The Review Team is responsible for review of key documents and preparation of written comments designed to strengthen documents, and which are reflective of their organization's mandates and/or positions (refer to **Section 1.4**). In addition to preparation of written comments, the members of the Review Team participated in periodic meetings and teleconferences to discuss Plan development, and will continue to be involved as the Plan is implemented (see **Sections 4.0** and **5.0**).

1.6 PREVIOUS STUDIES

Comprehensive hydrogeologic studies in the PAPA were completed pursuant to the 2008 ROD, fulfilling Step 2 of the ROD (see Section 4.2 in BLM 2008b). In 2007-2008, PAPA E&P operators commissioned a study to compile and analyze existing groundwater data and develop a hydrogeologic conceptual model. Geomatrix (2008) describes the correlation between groundwater-bearing units, groundwater flow, the interaction between surface and groundwater, and relationships between domestic, stock, and industrial wells. Their report is included in the Final SEIS for the Pinedale Anticline Oil and Gas Exploration and Development Project (BLM 2008a) and also identifies a number of data gaps in the hydrogeologic understanding of the PAPA.

In the 2008 ROD (see Section 4.2 in BLM 2008b), BLM determined that three steps were needed to be completed for groundwater resources. Step 1 is the compilation of existing information, and BLM determined that the Hydrogeologic Conceptual Model report prepared by Geomatrix in 2008 (http://www.blm.gov/wy/st/en/field_offices/Pinedale/pawg/DataResults.html) fulfilled this require-



ment. Step 2 is a characterization of the groundwater system, and Step 3 is a modification of the existing groundwater monitoring plan (i.e., this Plan).

Sections 1.6.1 through 1.6.3, below, are excerpts from the executive summaries of the three technical studies that were completed during Step 2 of the ROD, including:

- Hydrogeologic Data Gaps Investigation (AMEC 2012);
- Numerical Groundwater Modeling (AMEC 2013a); and
- Evaluation of Potential Sources of Low-Level Petroleum Hydrocarbon Compounds Detected in Groundwater (AMEC 2013b).

The executive summaries of these reports have been shortened and slightly adapted to fit with this Plan. Reports of these groundwater characterization studies have been accepted by the BLM and each of the study plans and reports are available for review or download from the BLM's Pinedale Field Office website (http://www.blm.gov/wy/st/en/field_offices/Pinedale/anticline/resources/water.html).

1.6.1 Hydrogeologic Data Gaps Investigation

BLM's 2008 ROD required that companies developing natural gas resources in the PAPA complete additional groundwater characterization. Data gaps in the understanding of the hydrogeologic system of the PAPA are identified in the Interim Plan (AMEC Geomatrix 2008). AMEC Environment & Infrastructure, Inc. (AMEC; previously AMEC Geomatrix, Inc. or Geomatrix) was retained to complete a hydrogeologic data gaps investigation on behalf of Ultra Resources, Inc. (Ultra), SWEPI LP (Shell), and QEP Energy (QEP) (known collectively as Operators). Based on a detailed Plan of Study issued in May 2009, AMEC completed extensive field investigations between 2009 and 2011, and reported on the results in May 2012 (AMEC 2012). That report describes results of the hydrogeologic data gaps investigation, culminating in a revision to the hydrogeologic conceptual model previously developed for the PAPA in 2008 (Geomatrix 2008).

Investigative work commenced in October 2009 and concluded in June 2011. Thirty study wells ranging in depths from 15 to 795 feet, and 13 shallow piezometers, were installed throughout the PAPA to characterize the groundwater system. Besides obtaining groundwater data (i.e., water elevations, water quality data, and aquifer testing data), synoptic flow studies and surface water quality analysis in the New Fork River were completed, two springs in the PAPA were characterized, and another area was evaluated for groundwater seeps. Collectively, these data were used to:

- Establish groundwater flow directions and gradients;
- Designate hydrostratigraphic units;
- Determine gain-loss characteristics of the New Fork River;
- Evaluate surface water / groundwater interconnection;
- Investigate the hydraulic connection between various water-bearing units;
- Develop a lithostratigraphic geologic model of the PAPA region;



- Generate a water balance for the groundwater system; and,
- Revise the hydrogeologic conceptual model of the PAPA.

The current understanding of the hydrogeologic system at the PAPA is based on findings from this Hydrogeologic Data Gaps Investigation and review of existing hydrogeologic data and literature. The hydrogeologic conceptual model was developed by synthesizing available geology, hydrology, hydrogeology, and water balance data for the PAPA. This conceptual model, in turn, forms the basis for the numerical groundwater flow model (see **Section 1.6.2**).

Beneath a majority of the PAPA is the Tertiary-age Wasatch Formation, consisting primarily of fluvially-deposited sandstone representing channel deposits, and shale/siltstone representing overbank deposits. About one-third of the Wasatch Formation in the study area consists of sandstone, with an average thickness of about 18 feet. About two-thirds of the Wasatch Formation consists of siltstone/shale with an average thickness of 33 feet. Sandstone and siltstone/shale are interbedded, laterally discontinuous on a scale of 1,000 feet, and vertical discontinuity can be on the order of 5 feet. Two other lithologic units are located in the PAPA, including alluvial deposits of sand and gravel present in stream valleys with depths typically less than 100 feet, and a veneer of terrace gravel over the Mesa.

The major conduits for groundwater flow in the PAPA include: Wasatch Formation sandstones, alluvium along the surface water courses, and glacial deposits draining the Wind River Mountains. Two hydrostratigraphic units (HSU) are defined for the PAPA: Alluvial HSU in the valleys of the principal rivers/streams; and Wasatch Formation (bedrock) HSU.

Groundwater in the PAPA generally flows west and south from the mountains and foothills toward the Green River below the mouth of the New Fork River and into the center of the Green River Basin. Groundwater in the shallow portions of the Wasatch HSU over much of the PAPA migrates vertically down to the underlying deeper or regional portions of the Wasatch HSU. In some isolated places, groundwater in sandstones of the Wasatch HSU may be perched. Groundwater in the Wasatch HSU preferentially flows through higher permeability sandstone units. Although not observed during this investigation, groundwater will flow preferentially along bedding planes and joints/fractures.

The lower New Fork River in the center of the PAPA is the major point of discharge for the Wasatch HSU and Alluvium HSU groundwater systems. South of this zone, groundwater flow paths are west-southwest toward the center of the Green River Basin. Vertical groundwater gradients measured in clustered wells of different depths support both the downward movement of groundwater in areas of the Wasatch HSU, and vertically upward groundwater movement along the New Fork River below the confluence of the East Fork River.

The Alluvial HSU is connected to the Wasatch HSU, receiving and transmitting water down valley and into the New Fork River in the central PAPA. Vertical gradients in alluvium in the upper New Fork River valley vary seasonally, but are upward most of the year. Artesian groundwater conditions in bedrock in the central portion of the PAPA cause Wasatch HSU groundwater to discharge into alluvium and the New Fork River.



Estimated groundwater velocity in alluvium is 30 times greater than velocities in Wasatch Formation sandstones. Given average hydraulic property data based on aquifer tests in 12 study wells and literature values for effective porosity, it may take groundwater 100 days to travel in alluvium the same distance that it would take 10 years in a sandstone unit of the Wasatch Formation.

Groundwater enters and exits the PAPA study area in various ways. Most groundwater entering the region is mountain front recharge that enters the area as underflow, while most groundwater leaving the region occurs as groundwater discharge to the New Fork River and Green River. Only about 3 percent of precipitation that falls within the PAPA recharges the groundwater system. Other recharge components are infiltration of irrigation water and leakage from irrigation ditches. Groundwater is removed from the system by evapotranspiration from wetlands and riparian phreatophytes. Only a relatively small amount of groundwater (less than one-half percent of total outflow and seven times less than precipitation recharge) is consumed by pumping (stock wells, domestic wells, and industrial wells).

The hydrogeologic conceptual model presented in the May 2012 report (AMEC 2012) is a revision to Geomatrix (2008) and describes groundwater occurrence, movement, and balance for the PAPA. This information supports the companion investigation into the sources of low-level petroleum hydrocarbon compounds (LLPHC) detected in some groundwater samples (see **Section 1.6.3**; AMEC 2013b) and became the hydrogeologic basis for the PAPA numerical groundwater model (see **Section 1.6.2**; AMEC 2013a).

1.6.2 Numerical Groundwater Modeling

The groundwater modeling report (AMEC 2013a) documents the conceptualization and design of a numerical groundwater flow model for the groundwater system in the PAPA. AMEC was retained to complete the numerical groundwater model on behalf of Ultra, Shell and QEP. NewFields has assisted AMEC in this modeling work since September 2012. The Hydrogeological Data Gaps Investigation (AMEC 2012) forms the basis for the numerical groundwater flow and transport models discussed below.

Modeling work was developed to achieve the following objectives:

- Construct a numerical model that is capable of simulating regional groundwater flow under steady-state conditions.
- Identify areas and specific receptors in the PAPA that are potentially vulnerable to contamination from natural gas activities should a significant release occur.
- Assess fate and transport of petroleum hydrocarbons and chloride that could potentially result from hypothetical releases.
- Predict the maximum lateral and vertical extent of impacts and maximum concentrations of contaminants in groundwater resulting from hypothetical releases.

1.6.2.1 Conceptual Model

Development of a conceptual model was the first step in the numerical modeling process. The majority of the PAPA is underlain by the Tertiary-age Wasatch Formation, consisting primarily of fluvially



deposited sandstones representing channel deposits, and shale/siltstone representing overbank deposits. Sandstone and shale/siltstone are interbedded, and laterally discontinuous. Other geologic units in the PAPA include alluvial sand and gravel deposits in stream valleys with depths typically less than 100 feet, and a veneer of terrace gravel over the highland area known as the Mesa. The majority of groundwater flow occurs within Wasatch Formation sandstone lenses, alluvial deposits along streams, and glacial deposits draining the Wind River Mountains. Groundwater generally flows west and south from the mountains and foothills toward the Green River below the mouth of the New Fork River and into the center of the Green River Basin. Groundwater preferentially flows through higher permeability sandstone units within the Wasatch Formation. The majority of groundwater within the Wasatch and alluvial groundwater systems discharges to the lower New Fork River in the center of the PAPA. South of the river, groundwater flows to the west-southwest toward the center of the Green River Basin. The alluvial groundwater system is connected to the Wasatch system, receiving and transmitting water down valley and into the New Fork River in the central PAPA. Based on contrasts in hydraulic conductivity between fine-grained units and sandstone, the discontinuous nature of individual sandstone beds, and hydraulic potentials that commonly rise above the top of the saturated zone, the Wasatch hydrostratigraphic unit in the PAPA is likely a semi-confined aquifer.

A groundwater balance was developed for the model domain based on field data and literature information. Mountain front recharge is the greatest source of groundwater. Other sources of recharge include natural recharge from precipitation and runoff, infiltration of irrigation water, and leakage from irrigation ditches. The majority of groundwater in the area discharges to the New Fork River. Groundwater also discharges from the system by evapotranspiration from wetlands and riparian phreatophytes, and by pumping from stock, domestic, and industrial wells.

1.6.2.2 Model Design

The model domain is 547 square miles inclusive of the PAPA boundary. The margins of the model domain are based on hydraulic boundaries. The model is bounded to the west by the Green River and to the south by a hydraulic divide and an underflow boundary defined by a potentiometric contour. The model is bounded to the east by the Big Sandy River and to the northeast by an underflow boundary defined by a potentiometric contour. The model contains 205 rows, 171 columns, and 69 layers with variable grid spacing. Model layers were defined by lithologic modeling incorporating data from 243 wells and represent alternating units of shale/siltstone with sandstone. The computer code MODFLOW-SURFACT was selected for the project because it has all the required capabilities for the study based on modeling objectives, the size and complexity of the project area, and hydrologic features expected to affect groundwater flow within the study area. Hydrologic boundary conditions in the model domain include general head boundary cells representing underflow; cells representing streams, rivers, and ditches simulated with the River Package; areal recharge simulated with the Recharge Package; evapotranspiration simulated with the Evapotranspiration Package; and pumping wells simulated with the Fracture Well Package.

1.6.2.3 Model Calibration

The model is calibrated to steady-state conditions represented by average annual groundwater elevation and flux targets. A set of 97 calibration head target values was developed based on



groundwater elevations measured in 2009, 2010, and 2011. Flux targets are based on estimates developed for the groundwater balance. Model calibration was completed using an iterative approach that included both manual and automated techniques (including parameter estimation using the PEST program) resulting in several hundred model iterations. Horizontal and vertical hydraulic conductivity and stream channel and ditch bottom conductance values were adjusted during calibration to minimize residuals. Qualitative and quantitative evaluation of results indicates the model is well calibrated.

A sensitivity analysis was performed on the calibrated steady-state model by systematically adjusting parameters within a reasonable range to see the effect on calibration statistics. The calibration is least sensitive to evapotranspiration rate and extinction depth and most sensitive to horizontal hydraulic conductivity and total recharge.

1.6.2.4 Transport Simulations

Advective and solute transport modeling was completed to meet the project objectives. Advective transport was simulated using particle tracking techniques and MODPATH software. Particle tracking was used to identify areas and specific receptors in the PAPA that are potentially susceptible to contamination from natural gas activities should a significant release occur. Potential sources of groundwater contamination associated with natural gas operations and potential receptors of concern in and around the PAPA were identified. Potential sources include shut-in pre-1984 natural gas wells, liquid-gathering facilities, natural gas pads, pipelines, roads, and produced water disposal facilities. Forward and reverse particle tracking methods were used to evaluate flow paths and advective travel times from potential sources to potential receptors. For advective modeling, the following conservative assumptions were used:

- A travel time of 110 years, which is twice the expected life of natural gas production in the PAPA based on BLM (2008b);
- Dissolved contaminants move at the same velocity as groundwater and the effects of dispersion were not modeled; and
- Based on uncertainty analysis, minimum and maximum values for recharge, effective porosity, and hydraulic conductivity were used.

Solute transport modeling was performed in the area determined from advective modeling to be most susceptible to groundwater quality impacts to assess fate and transport of certain petroleum hydrocarbon compounds and chloride that could potentially result from five hypothetical release scenarios:

1. Truck spill of condensate on Paradise Road;
2. Pipeline leak of produced water north of the New Fork River and south of the Mesa;
3. Spill of condensate due to failure of a storage tank at a liquid-gathering facility;
4. Frac-tank spill on a natural gas pad; and
5. Leak from shut-in pre-1984 natural gas well Pinedale 3.



Source terms for each scenario were developed based on the conservative assumptions including:

- The hypothetical releases represent worst-case scenarios in which all best management practices (BMPs) fail, there is no remediation, the release is instantaneous, and all liquids reach the subsurface;
- A travel time in groundwater of 110 years, which is twice the expected life of natural gas production in the PAPA based on BLM (2008b); and
- When simulating the fate of chloride, no degradation or adsorption to the aquifer matrix occurs.

Modeling included predicting the maximum lateral and vertical extent of impacts and maximum concentrations of contaminants in groundwater resulting from hypothetical releases. This analysis does not represent actual contamination in the aquifer, but instead was used to evaluate flow paths and travel times from hypothetical sources and receptors and to demonstrate model capabilities.

1.6.2.5 Findings

Outputs generated through fate and transport modeling resulted in the following key findings:

- Natural gas activities in the PAPA will not affect groundwater in or around the town of Pinedale.
- In general, particles in groundwater do not travel more than 1.5 miles in 110 years in areas within the PAPA outside of the river corridors. Based on solute transport modeling, only conservative solutes (those that do not adsorb to aquifer material, react chemically, or undergo biological degradation), such as chloride, would travel this distance. Traveling at the average linear groundwater velocity in the Wasatch Formation, it would take a particle 9 years to travel the typical width of an individual natural gas well pad (650 feet).
- The area most susceptible to groundwater quality impacts related to a significant release (e.g., catastrophic failure of a 6,300 gallon tank) to groundwater from natural gas activities is the New Fork River valley between Boulder Creek and the downstream PAPA boundary. This conclusion is based on conservative assumptions presented above and the combination of this area's proximity to potential downgradient source areas, relatively rapid groundwater travel times, and existing receptors including the New Fork River and groundwater users. Results suggest future groundwater monitoring should include this area.
- Results of five hypothetical release scenarios simulated within the area most susceptible to groundwater quality impacts, as described above, indicate that predicted concentrations of benzene and toluene in groundwater do not exceed EPA maximum contaminant levels for drinking water at distances greater than 150 feet away from simulated sources. Since most of the potential receptors in this area are greater than 150 feet from oil and gas activities, and even if a major release to groundwater were to occur within this area, impacts related to petroleum hydrocarbons would be unlikely to reach most of these receptors.
- An individual release of petroleum hydrocarbons from natural gas exploration and production activities is unlikely to impact large portions of the Wasatch or alluvial aquifers due to relatively low groundwater velocities, retardation, and biodegradation.



- The numerical model is appropriate for predicting flow and transport at an intermediate and regional scale. The model results are helpful in identifying regions within the aquifer system (and in rivers/streams where groundwater is connected to surface water) that are most susceptible to groundwater quality impacts, and identifying appropriate locations for long-term water quality monitoring.

1.6.2.6 Limitations

There is a scarcity of groundwater elevation data outside the development area of the Pinedale Anticline. Consequently, groundwater elevation targets for the model are concentrated in and around the axis of the Pinedale Anticline which can lead to increased model uncertainty.

The transport model described above has not been calibrated to existing conditions because information regarding source terms (e.g., contaminants in the groundwater system) is not available. For this reason, the predictive capabilities of the transport model have not been evaluated. Conservative assumptions were used for solute transport model inputs.

Model cells are larger than the areas within which the hypothetical contaminant releases were assumed to occur. Because of the model cell size, the model cannot simulate small-scale (<300 feet) heterogeneity in the unsaturated and saturated zones. As a result, the model is not capable of accurately simulating concentrations of contaminants of concern at a small-scale (<300 feet); however, the model is appropriate for simulating large-scale (>300 feet) movement of potential releases and travel times from potential sources to potential receptors.

Limited information is available regarding the location of fractures and faults in the Wasatch Formation, and no information is available regarding hydraulic properties of fractures and faults. Fractures and faults can act as both conduits and barriers to flow and contaminant transport. For this reason, the model assumes that groundwater flows through a porous medium and that no preferential flow occurs through fractures in the Wasatch Formation. In reality, some preferential flow paths associated with geologic structure and secondary porosity likely exist; permeable fractures could affect groundwater flow directions and transport velocities.

1.6.3 Evaluation of Potential Sources of LLPHC in Groundwater

AMEC (2013b) documents the evaluation of low levels of organic chemicals or constituents detected in groundwater samples collected from water wells in the PAPA. *Low levels* refer to concentrations of organic constituents less than regulatory standards for groundwater. AMEC, in association with NewFields (since September 2012), conducted this independent investigation under contract to three oil and gas companies (Ultra, QEP, and SWEPI LP). The LLPHC study was required under terms of the 2008 ROD (BLM 2008b).

The investigation identified no evidence of widespread impacts to groundwater in the PAPA as a result of natural gas exploration and production. Evaluation of the potential sources of organic chemicals considered in this study identified the following known or likely sources of low levels of organic constituents in water wells:



- Upward seepage by natural processes of natural gas from deep, underlying gas reservoirs over time into overlying geologic layers where groundwater occurs;
- Organic constituents introduced into water wells during drilling, installation, and operation of the well; and
- Naturally occurring organic matter in groundwater or associated with particles suspended in well water during sample collection.

Organic constituents introduced during drilling, installation, or operation of a water well, as well as particles of organic matter suspended in well water during sample collection, would not reflect groundwater conditions beyond the immediate vicinity of the well. Upward seepage of natural gas into groundwater and naturally occurring organic matter in groundwater reflect natural conditions. The sources of low-level organic constituents detected in some wells may be a combination of both organic material introduced into the wells and other organic material that occurs naturally. In many cases, it is impossible to differentiate between natural and man-made sources.

1.6.3.1 Background

Water supply wells have been installed throughout the PAPA to provide water needed for natural gas exploration and production activities, which began in the PAPA in 1939. Groundwater samples have been collected from water wells in the PAPA annually since 2004. Low levels of organic constituents, which have been previously reported as *petroleum hydrocarbons* (AMEC 2010), have been detected in groundwater samples collected from a number of these water supply wells. This study was conducted to identify and evaluate the sources of these low-level organic constituents.

1.6.3.2 Definition of Petroleum Hydrocarbons

Hydrocarbons are organic chemical compounds that contain varying numbers of carbon and hydrogen atoms. Refined petroleum products and unrefined petroleum extracted from the ground (crude petroleum) contain mixtures of many individual hydrocarbon compounds, which are referred to as petroleum hydrocarbons. Mixtures of hydrocarbons and other organic compounds also occur naturally in organic matter associated with groundwater or sediments. Laboratory methods have been developed by state and federal agencies to analyze for the presence of and determine the composition of mixtures of hydrocarbons. The methods used in this study were originally developed primarily to identify the types of hydrocarbons found in crude petroleum and refined petroleum products. However, these methods detect a broad range of organic constituents that include both hydrocarbon and non-hydrocarbon compounds and that can originate from both petroleum-based and non-petroleum sources.

Additional laboratory tests can be used to identify other specific chemicals present in the mixture. The specific types and amounts of chemicals present in the mixture produce what is called a chemical signature. The chemical signatures of mixtures of organic compounds can be used to help identify the potential source of these compounds. Likewise, the chemical signatures of different samples can be compared to assess whether they originate from the same source.



1.6.3.3 High-Level versus Low-Level Detections

This study sought to identify sources of low levels of organic constituents identified in samples from water wells. Low-level means that detected concentrations are less than regulatory standards (applicable groundwater standards), and in most cases more than 10 times or even 100 or more times lower.

A few water wells in the PAPA sampled for this study contained high-levels of organic constituents. High-level means that concentrations are above the applicable groundwater standards. The Wyoming DEQ, Voluntary Remediation Program (VRP), is overseeing cleanup and/or further investigation of the few cases where high levels of organic constituents have been identified in water wells. The nature of the high-level detections, as well as the potential sources of the high-level detections, were not the focus of the LLPHC study.

1.6.3.4 Results of Sampling and Analysis

AMEC (2013b) collected samples of various materials that could be potential sources of low-level organic constituents in water wells as part of a sampling and analysis plan that was developed for this study and accepted by BLM in consultation with the EPA and DEQ. The potential source materials represent a variety of materials used in, or by-products of, natural gas E&P activities, including the natural gas produced from the gas wells (AMEC 2013b). Samples of groundwater and gas were collected from water wells selected for sampling in the PAPA (AMEC 2010). All samples were analyzed for a broad suite of organic constituents and other chemicals. The chemical signatures of groundwater samples collected from water wells were then compared to those of the material samples to identify if any of these materials could be contributing to low-level detections of organic constituents in the water wells. Sampling and analysis followed the sampling and analysis plan accepted by the BLM in consultation with the EPA and DEQ (AMEC 2010).

The sampling results identified two main chemical signatures for organic constituents detected in groundwater samples:

- Low-level detections of volatile organic constituents; and
- Low-level detections of semivolatile organic constituents.

Volatile and semivolatile organic constituents are general categories of organic constituents that are based on the volatility of the constituent (i.e., how easily the chemical evaporates). Volatile organic constituents are generally made up of smaller, volatile molecules, such as methane, which is generally the most abundant component of natural gas. Semivolatile organic constituents are generally made up of larger, less volatile molecules, such as naphthalene. These types of organic constituents may originate from a different source or sources. They occur in petroleum-containing substances, but also commonly occur naturally under a variety of conditions.

1.6.3.5 Potential Sources of Existing Low-Level Organic Constituents

The following potential sources of the organic constituents detected in water samples were identified in the sampling and analysis plan (AMEC 2010):



- Natural gas wells;
- Natural gas facilities, such as pits, pipelines, and storage tanks;
- Injection wells for wastewater disposal;
- Known waste facilities or contaminated sites unrelated to natural gas E&P activities;
- Products and practices associated with water supply wells;
- Sampling and laboratory procedures;
- Upward seepage of natural gas by natural processes; and
- Naturally occurring organic matter.

1.6.3.6 Low-Level Detections of Volatile Organic Constituents

The low-level detections of volatile organic constituents in water wells consisted primarily of hydrocarbon gases, based on chemical testing of the groundwater samples. The chemical signatures of gas in samples obtained from water wells did not match the chemical signatures of natural gas produced from natural gas production wells. Therefore, the low-level detections of volatile organic constituents in water wells were determined to not be directly linked to leaking natural gas wells or activities related to natural gas development. It is unknown what caused the chemical signature of gas present in groundwater to change relative to the natural gas produced in the PAPA. Changes to the chemical signatures of gas can occur by natural processes when natural gas moves from one place to another.

Natural gas is generated in source rocks at great depth in the PAPA. This natural gas has moved upward until reaching relatively impermeable rock that traps the gas in an underground reservoir. Some natural gas seeps through the trap into the overlying geologic formations where groundwater occurs. The chemical signature of natural gas likely changes as the gas moves up through the thick layers of rock over geologic time. Where the gas comes in contact with groundwater, a portion of the natural gas becomes dissolved in groundwater. Gas can also move upward from groundwater in a water well into the air space below the well cap. Studies conducted at other gas fields have shown that natural gas tends to move upward to the ground surface over time. Moreover, the presence of gas in groundwater has been noted in water wells in the PAPA before natural gas wells had been drilled in those areas. Therefore, based on geologic conditions, the presence of natural gas in near-surface groundwater is expected as a natural condition in the PAPA.

1.6.3.7 Low-Level Detections of Semivolatile Organic Constituents

Semivolatile organic constituents were also detected at low-levels in water wells sampled for this study. The semivolatile organic constituents present in water wells do not appear to be related to the volatile organic constituents present in water wells.

It is difficult to pinpoint the exact source of most of the low-level semivolatile organic constituents due to the absence of a distinctive chemical signature at most wells; however, these chemical signatures clearly do not match the chemical signatures of most potential source materials sampled for this study. Low-levels of semivolatile organic constituents detected in water well samples appear to be related to



one or more of the following materials, most of which are associated with drilling, construction, or use of the water well itself:

- Substances that are used or handled while drilling, installing, and operating water wells; and/or
- Naturally occurring organic matter present in groundwater or associated with particles of sediment suspended in well water during sample collection.

Organic constituent detections resulting from water well drilling, installation, and operating practices would primarily affect the quality of water inside the well with minimal or no impact to groundwater quality beyond the immediate vicinity of the well.

1.6.3.8 No Widespread Impact to Groundwater in the PAPA

This study did not produce any evidence of widespread impact to groundwater in the PAPA as a result of natural gas E&P operations through releases of condensate, produced water, drill mud, flowback fluid, natural gas, or other materials used or generated during these operations. The chemical signatures of organic constituents in wells with low-level detections indicate that widespread releases of sampled potential source materials from natural gas production wells and other E&P facilities (pipelines, produced water injection wells, pits, tanks, centralized liquid gathering facilities [CGFs], and liquids gathering systems [LGS]) have not occurred. Volatile organic constituents detected in low-level wells are largely sourced from the upward seepage of natural gas from depth by natural processes that have likely occurred over geologic time. Low levels of semivolatile organic constituents detected in water wells are likely sourced from substances used in the drilling, installation, and operation of water wells or from naturally occurring organic matter present in the Wasatch Formation sediments. In addition to the chemical evidence, evidence from temporal, spatial, physical, and operational factors support the finding that no widespread impact to groundwater has occurred from E&P activities.

Several temporal and spatial factors support the conclusion that there is not widespread impact to groundwater in the PAPA including:

- Low-level detections were reported before the development and establishment of CGFs, LGS, and injection wells for disposal of produced water. Because low levels of organic constituents had already been detected before these facilities were fully developed, the potential sources are not likely the sources of existing low-level detections.
- Many low-level organic constituent detections are not consistently reported between annual sampling events performed by the Sublette County Conservation District (SCCD), which could be attributed to several factors; however, this finding is not consistent with a continuous and widespread source of organic constituents.
- The distribution of the low-level detections of semivolatile organic constituents in the PAPA is not characteristic of a large, continuous plume of contaminants, or multiple plumes of contaminants originating from E&P activities. High-level detections of organic constituents observed at some gas well pads are isolated and do not appear to be contributing to these low-level semivolatile (or volatile) organic constituent detections in water wells, based on the chemical evidence gathered during this study and the historical groundwater sampling record.



- Several potential off-pad sources (e.g., landfills, listed underground storage tank sites, or hazardous waste sites) are not considered likely sources of organic constituents in water wells because of their location away from the main gas field development areas, the degree of regulatory oversight or regulatory closure achieved (e.g., permitted oil disposal facilities, landfills), or their location hydraulically downgradient of most water wells in the PAPA (most produced water injection wells).

The hydrogeology of the PAPA, as well as the fate and transport properties of solutes in the unsaturated and saturated zones, control the likelihood that a release from any of the potential E&P point sources would impact groundwater. The results of the Hydrogeological Data Gaps Investigation (AMEC 2012) and the Numerical Groundwater Modeling of flow and solute fate and transport (AMEC 2013a) support the findings of this study with respect to the observed distribution of organic constituent detections in groundwater in the PAPA.

Assuming no preferential pathways exist in the Wasatch Formation, the volume of any spill or release would need to be substantial in order to reach groundwater in the Wasatch Formation in areas along the crest of the Pinedale Anticline where concentrated E&P activities occur. A hypothetical release would typically have to migrate vertically over 200 feet (and up to 500 feet in some places) through the unsaturated (vadose) zone to reach the regional groundwater system in the Wasatch Formation. A spill or release large enough to reach groundwater, or occurring directly in the Wasatch Formation, would migrate slowly in groundwater within the Wasatch Formation due to the relatively low velocity of groundwater in this unit. This velocity ranges from 0.011 to 40 feet per year, based on the observed range of hydraulic gradients and the range of hydraulic conductivity values determined from aquifer testing by AMEC (2012). Based on these velocity estimates, it would take at least 5 years for groundwater to travel the width of a typical gas well pad.

When release scenarios were modeled using the groundwater model, widespread plumes of organic constituents did not develop in groundwater, which is consistent with the hydrogeological data collected by AMEC (2012), the chemical data collected annually by the SCCD, as well as the results of this study. Results of hypothetical release scenarios simulated within the area most susceptible to groundwater quality impacts (e.g., New Fork River corridor in the center of the PAPA) indicate that predicted concentrations of benzene and toluene in groundwater do not exceed applicable groundwater standards at distances greater than 150 feet from simulated sources (AMEC 2013a).

Based on what is known about the hydrogeology in the PAPA, as well as the fate and transport of organic constituents, low levels of organic constituents detected in water wells are not the result of large releases from E&P activities. Not enough time has elapsed since the beginning of E&P operations in the PAPA (~1939) to the timing of this study (i.e., 2010) for a widespread plume of organic constituents to develop in groundwater and result in the low-level organic constituent detections observed in the PAPA. In addition, based on chemical data collected for this study and by the SCCD, widespread plumes of organic constituents are not evident, and high-level organic constituent detections appear to be isolated in nature.



Implementation of environmentally responsible best management practices during natural gas development (refer to **Section 3.0**) and rigorous oversight by regulatory agencies further minimize the potential for impacts to groundwater:

- Secondary containments and closed-loop systems are increasingly used.
- Modern well casing and cementing programs are employed in the construction of natural gas production wells.
- Well integrity testing of natural gas wells and pressure monitoring are employed during hydraulic fracturing operations.
- Permitting and reporting requirements as prescribed by the state and federal agencies are followed by Operators, and E&P activities are subject to compliance inspections during the drilling and production phases.

1.6.3.9 Summary of Findings

Analysis of the evidence and data gathered in this study produced four main conclusions.

1. Low-level volatile organic constituents detected in groundwater are largely attributable to natural gas that seeps upward from deep geologic layers and into groundwater by natural processes over time.
2. The source or sources of semivolatile organic constituents detected at low-levels in groundwater samples is not readily apparent. These constituents likely originate from the products and practices used to drill, install, or operate water wells and/or from naturally occurring organic matter present in groundwater or associated with particles of sediment suspended in water wells during sample collection.
3. No widespread impact to groundwater in the PAPA is evident as a result of spills or leaks of materials used in, or by-products of, natural gas development.
4. Based on this study, no additional measures are necessary to mitigate either the low-level volatile or semivolatile organic constituents detected in water wells in the PAPA.

These conclusions do not mean that releases from natural gas exploration and production activities could not affect groundwater in the future. Continued application of environmentally responsible best practices during these activities will help protect groundwater resources. Ongoing groundwater monitoring will help identify potential changes to groundwater conditions in the future.

1.7 GROUNDWATER MONITORING DATA SOURCES

Groundwater data used to develop this Plan were derived from a variety of sources which are specifically referenced in Geomatrix (2008) and AMEC (2012, 2013a, 2013b). The following sections summarize groundwater data generated by both the SCCD and AMEC. **Section 1.7.3** provides a description of the environmental data management system that is being used to store, manage and report groundwater data collected for the PAPA.



1.7.1 Sublette County Conservation District

The SCCD has assisted the operators in collecting various groundwater data in the PAPA since the BLM issued the 2000 ROD (BLM 2000). Per requirements of the 2000 ROD, groundwater quality in water wells within one-mile of E&P activities has been monitored on an annual basis. Analytical parameters include general water quality constituents, common ions, metals, and petroleum hydrocarbons. Sampling has been conducted annually from 2004 through 2014.

SCCD organizes water quality data in a Microsoft Access™ (Access) database. On an annual basis they provide results of water quality sampling to well owners and prepare an annual report which is issued to BLM's Pinedale Field Office. A summary of results is presented during annual planning meetings between BLM, operators, and the public, typically in late fall or early winter of each year. Water quality reports issued by SCCD are available at:

http://www.blm.gov/wy/st/en/field_offices/Pinedale/pawg/DataResults.html.

1.7.2 AMEC

As part of completing the technical studies described in **Sections 1.6.1** through **1.6.3**, SCCD's data were converted into a geodatabase. AMEC (2009) presents the results of converting SCCD's database into an ArcGIS geodatabase using Access as the software platform. The main components of the geodatabase are feature datasets, feature classes and tables. Feature datasets contain vector spatial layers, also called feature classes, which are related by theme (Wells and BLM shapefiles) and have the same spatial reference (coordinate system and projection). Tables are not contained within feature datasets but instead exist at-large within the geodatabase. Tables are, however, related to specific feature classes by a common field. For example, the *Wells* feature dataset includes a point feature class called *All_Wells*, which is related to all the tables within the geodatabase. Some examples of tables that are joined/related by the WID (Well ID) field are *Water Well Analytical Data*, *Water Well Field Data*, and *Water Well Water Levels*.

The PAPA geodatabase assembled by AMEC included SCCD data through 2011 and groundwater data generated through the completion of the Hydrogeologic Data Gaps Investigation and LLPHC study. The PAPA geodatabase was transmitted to BLM on February 20, 2014.

1.7.3 NewFields' Environmental Data Management System

In 2014, NewFields organized hydrogeologic data in the PAPA geodatabase into NewFields' Environmental Data Management System (EDMS). The EDMS is hosted in Access which easily exports to Microsoft Excel™ and other commonly-used software. NewFields database schema is more efficient to analyze data and better integrates with geographic information systems (GIS). Key benefits of EDMS include:

- Seamless import of analytical laboratory electronic data deliverables (EDDs);
- Built-in quality control checks which minimize user input and displays inconsistencies within the database;



- Standardized analyte lists, chemical abstracts service (CAS) numbers, and analytical units that allow for accurate and efficient data analysis;
- High level of customizability allowing EDMS to be modified to fit the user's needs. In addition, EDMS can be formatted to the risk based data management system (RBDMS) being used by DEQ Water Quality Division to manage water quality data, allowing efficient transfer of data from EDMS into the DEQ RBDMS;
- Built-in standardized queries/scripts for commonly performed analyses, such as identifying trends and/or approaching a defined threshold;
- Full integration with GIS interfaces; and
- Exports to customized web-based mapping tools.

After converting the PAPA geodatabase into EDMS, NewFields updated the database using additional publically available datasets including:

- Well inventory information developed by SCCD pertaining to well types, ownership, and current (2014) status (i.e., active, plugged and abandoned [P&A], no longer in SCCD sampling area);
- Analytical sampling results from SCCD's annual groundwater monitoring in the PAPA for 2012 and 2013; and
- 2006-2007 analytical sampling results from Operators which were submitted to DEQ.

SCCD groundwater data is collected in strict accordance with a Water Quality Monitoring Sampling and Analysis Plan (SCCD 2008). In addition, SCCD has prepared a Ground Water Monitoring Manual and Protocol document (SCCD 2014) for their sampling work. These documents prescribe data collection and management procedures including in-house data verification protocols. By following these two data collection documents, SCCD has maintained a high level of consistency in their dataset making it reliable for specific purposes in developing the Groundwater Monitoring Program (see **Section 4.0**).

It is important to note that NewFields considers all analytical data in the database "qualified as estimated", with the exception of analytical data collected by AMEC in 2010-2012 while executing the Hydrogeologic Data Gaps Investigation (AMEC, 2012) and Low-Level Petroleum Hydrocarbon Compound Study (AMEC, 2013b). Based on these reports, analytical data qualified as "estimated" means that:

The analyte was positively identified and the associated numerical value is the approximate concentration of the analyte in the sample (due either to the quality of the data generated because certain quality control criteria were not met, or the concentration of the analyte was below the laboratory's practical quantitation limit).

Independent Operator data in the database have not been verified or validated, and SCCD data validation procedures have not been as strict as those used in AMEC (2012 and 2013b). For these reasons, Operator and SCCD data are considered "estimated" for the following reasons including:



- Uncertainty in measurement procedures and field protocols;
- Laboratory analytical methods and/or detection limits that have changed over the period of the various records;
- Potential false positive and/or misidentified constituents using EPA Method 8021 versus EPA Method 8260;
- Small sample sizes;
- Uncertainty in the use of quality control procedures and data validation; and
- Problems associated with data presentation and/or transcription.

The Hydrogeologic Data Gaps Investigation and LLPHC Study were completed under applicable environmental industry protocols and under plans accepted by BLM, DEQ, and EPA. Analytical data generated from these two studies have been validated and qualified when required.

Groundwater data in the Pinedale EDMS are also being converted to DEQ's RBDMS format. It is anticipated that the DEQ's RBDMS will store a variety of water quality data obtained in Wyoming and be available to the public. These data are envisioned to include water quality data for sites managed under Wyoming regulatory programs (e.g., Storage Tank and GEM Underground Injection Control programs) and from Wyoming's ambient groundwater quality monitoring program (Boughton 2014). It is anticipated that data in the Pinedale geodatabase will be incorporated into the RBDMS.

Lastly, based on letters sent to QEP and Ultra from BLM's Pinedale Field Office, dated February 4, 2015, operators within the Pinedale Field Office Management Area are requested to utilize a geodatabase system for all groundwater quality data collected to date and in the future that is compatible and capable of being accessed by WOGCC's RBDMS. The letter states that the WOGCC will issue an Electronic Data Deliverable format for their RBDMS in order to manage groundwater data pursuant to the new baseline rule.

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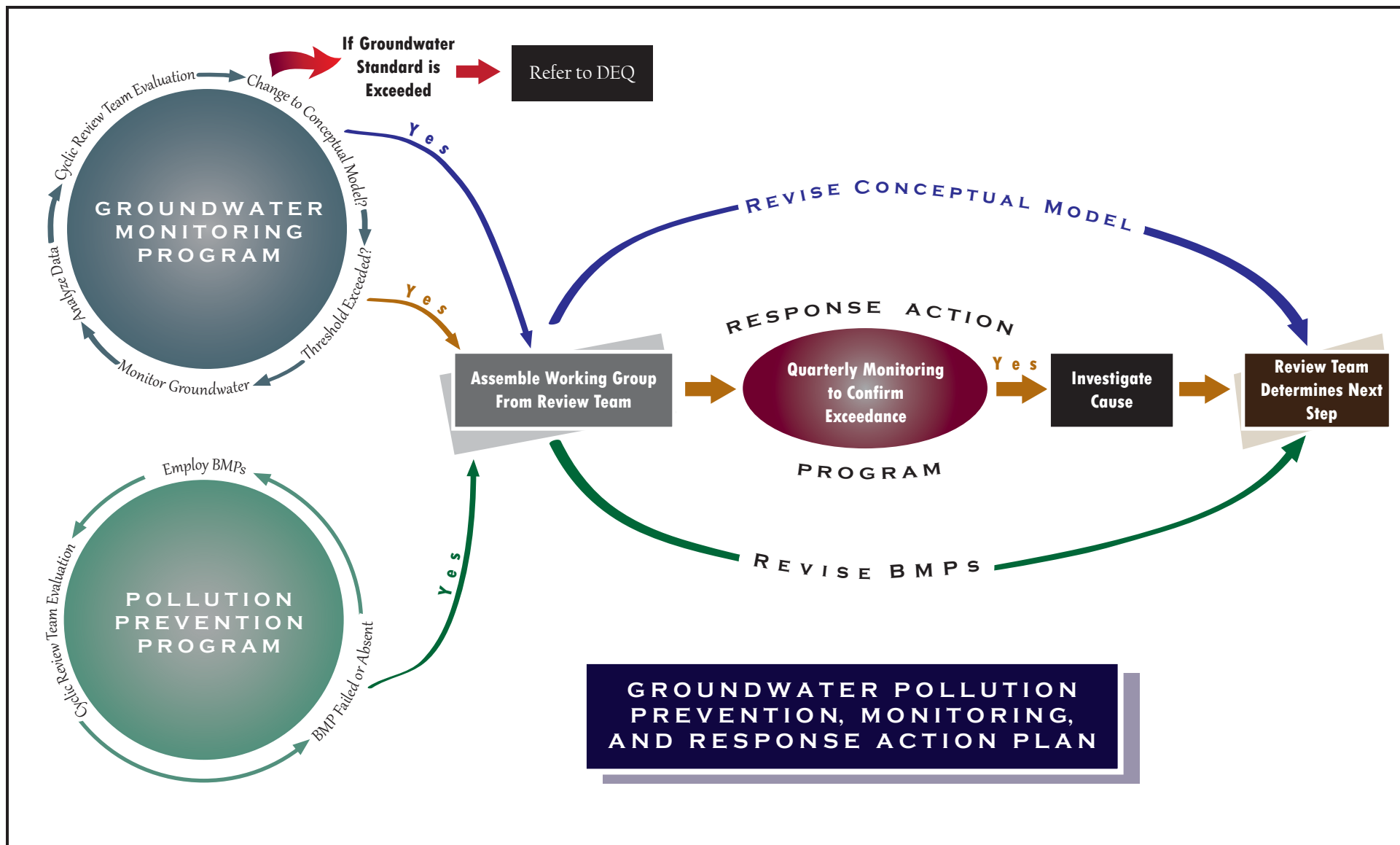
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FIGURES



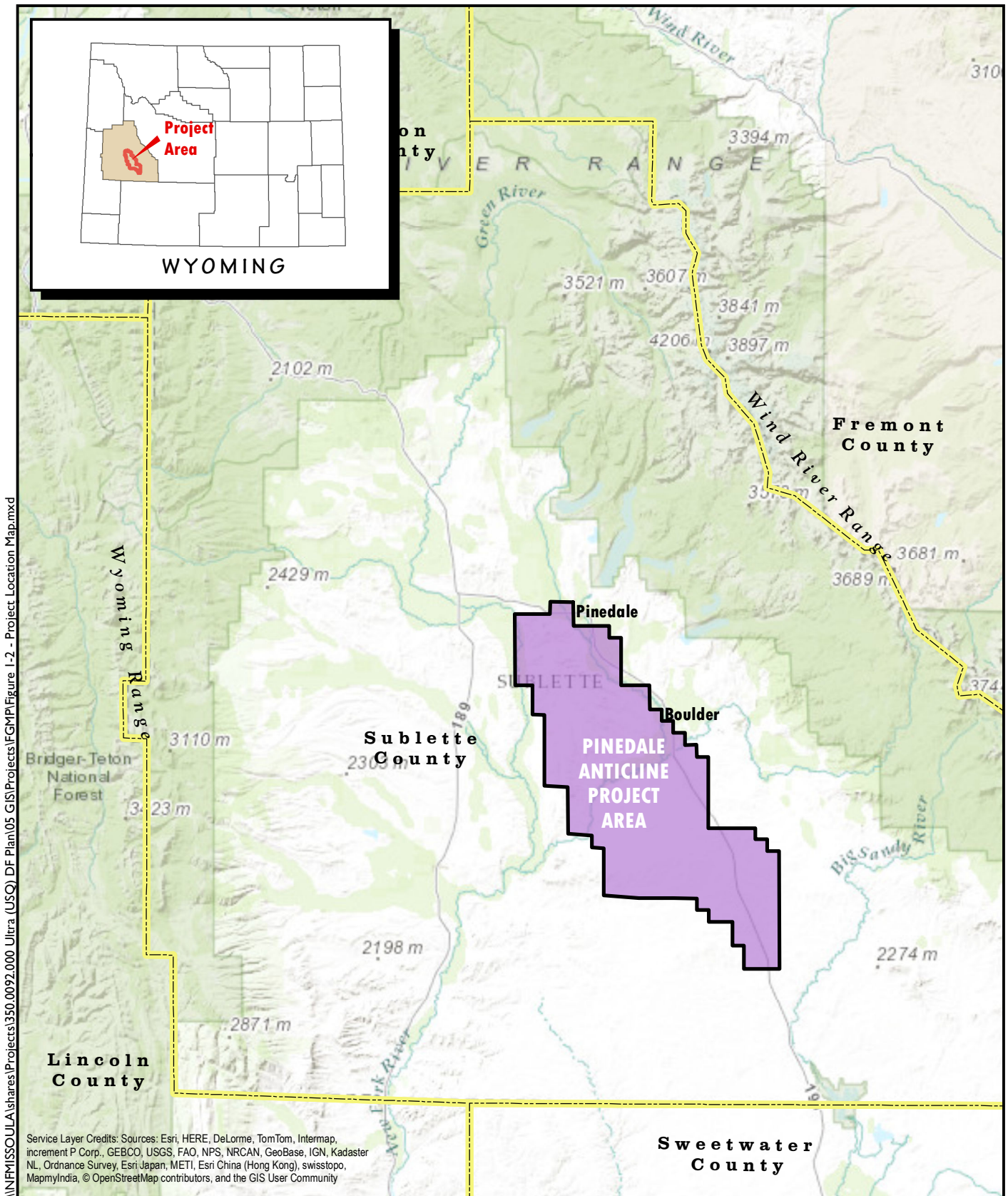


Notes:

BMP - Best Management Practices

Review Team - Regulatory & Operator Representatives

Conceptual Model - Hydrogeologic Conceptual Model

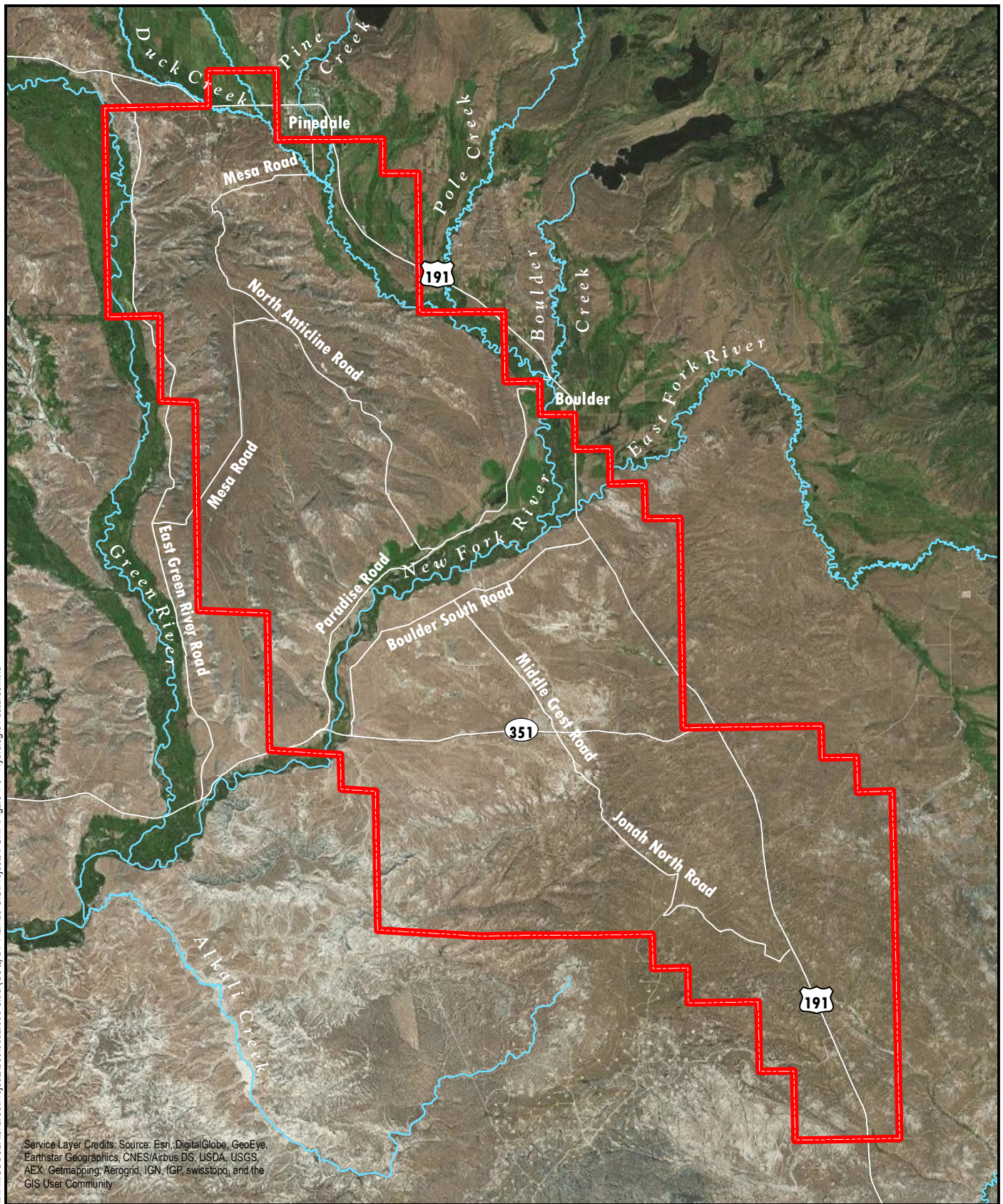


0 20
Miles

NewFields

Project Location Map
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 1-2

\\NFMSOULA\shares\Projects\350.0092.000 Ultra (USQ) DF Plan\05 GIS\Projects\FGMP\Figure 1-3 - Hydrologic Features.mxd



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



NewFields

 Pinedale Anticline Project Area

Hydrologic Features
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 1-3

PROJECT OVERSIGHT

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AUTHORIZED OFFICER BLM

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PROJECT LEAD BLM

KELLY BOTT
CONTRACT MANAGER
UQ COORDINATOR

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Kate Helm - WOGCC

Mark Thiesse - DEQ

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Lily Barkan Lee - DEQ

Andrew Schmidt - EPA

OPERATOR TEAM

Kelly Bott - Ultra

Debbie Stanberry - QEP

Patrick Ash - Ultra

Christy Woodward - QEP

Current as of January 2016



BLM - Bureau of Land Management
DEQ - Wyoming Department of Environmental Quality
SEO - Wyoming State Engineer's Office
WOGCC - Wyoming Oil & Gas Conservation Commission
EPA - U. S. Environmental Protection Agency
UQ - Ultra Resources, Inc. and QEP Energy Company

Project Organization
Groundwater Pollution Prevention, Monitoring and
Response Action Plan
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 1-4